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Fourth Industrial Revolution Technologies in Nigerian Libraries: Implications for Human Capital Development and Digital Innovation

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ABSTRACT

Background: Fourth Industrial Revolution (4IR) technologies are increasingly transforming knowledge institutions, including libraries, through automation, smart systems, and digital service innovation. In Nigeria, however, the adoption of these technologies remains uneven despite their potential to enhance institutional efficiency, strengthen digital innovation, and support human capital development

Purpose: This study examines the adoption of 4IR technologies in Nigerian libraries and analyzes their implications for human capital development and digital innovation

Methods: This study employs a systematic review approach by synthesizing relevant literature published between 2015 and 2024. The review focuses on patterns of adoption, implementation barriers, and the developmental implications of 4IR technologies in the Nigerian library sector.

Results: The findings indicate that awareness of 4IR technologies among library professionals has increased, but actual implementation remains limited. Key barriers include inadequate funding, weak digital infrastructure, limited technical expertise, and insufficient institutional readiness. Nevertheless, some Nigerian libraries have begun adopting automation tools, RFID systems, and digital content management practices. These developments suggest that 4IR technologies may contribute to human capital development by improving digital competencies, expanding access to knowledge resources, and supporting more innovative learning and research environments. They may also promote digital innovation through greater service efficiency and improved information management.

Conclusions: Although still at an emerging stage, the adoption of 4IR technologies in Nigerian libraries has significant potential to support human capital formation and digital innovation within the knowledge economy. Realizing this potential requires stronger policy support, sustained investment in infrastructure, and continuous capacity building for library professionals.

Research Contribution: This study contributes to the literature by repositioning 4IR adoption in Nigerian libraries within the broader discourse of human capital development and digital innovation, thereby strengthening its relevance to economic development studies.

Keywords: fourth industrial revolution, nigerian libraries, technology adoption, smart libraries, ICT integration, digital transformation

INTRODUCTION

The Fourth Industrial Revolution (4IR), characterized by rapid technological

convergence and the fusion of digital, physical, and biological systems, is reshaping how knowledge is created, accessed, and disseminated. Technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), robotics, big data analytics, blockchain, and virtual and augmented reality are increasingly influencing a wide range of sectors, including education and information services (Logeswaran et al., 2024). Libraries, as strategic institutions for knowledge production, preservation, and dissemination, are not exempt from this transformation (Sandhu, 2018). In many advanced economies, libraries have begun integrating 4IR technologies to automate services, personalize user experiences, support research through advanced data tools, and expand access to digital content. These developments suggest that libraries are no longer merely service units for information access, but also potential actors in strengthening digital innovation and supporting knowledge-based development.

In developing countries such as Nigeria, however, the adoption of 4IR technologies in libraries remains relatively low and uneven. Nigerian libraries, particularly academic and public libraries, continue to face structural barriers such as inadequate infrastructure, limited digital competencies among staff, weak institutional support, insufficient funding, and the absence of clear policy frameworks for technological modernization (Haruna, 2025). Although previous technological transitions, including digitization and automation, have gradually taken root in some institutions, the complexity and pace of 4IR demand a more deliberate and coordinated response. Nigeria provides a relevant context for this analysis because of its large population, expanding education sector, and persistent challenges in digital infrastructure, institutional capacity, and technological modernization. These conditions make Nigerian libraries an important case for understanding how technological transformation in knowledge institutions may intersect with broader developmental challenges in emerging economies.

The developmental relevance of this issue lies in the role libraries can play within the knowledge economy. As institutions that support learning, research, digital access, and information management, libraries contribute to human capital formation by improving access to knowledge resources, strengthening digital competencies, and facilitating more innovative educational and research environments (Haruna, 2025). The adoption of 4IR technologies may further enhance this role by enabling more efficient service delivery, better information organization, expanded remote access, and more responsive user support systems. From this perspective, technological transformation in libraries is not merely an institutional or technical matter; it is also linked to human capital development and digital innovation, both of which are central concerns in contemporary economic development discourse.

Despite this potential, empirical understanding of the status, depth, and implications of 4IR adoption in Nigerian libraries remains limited and fragmented. Existing studies have largely discussed ICT integration in libraries, but comprehensive and up-to-date analysis focusing specifically on 4IR technologies is still lacking (Adekoya et al., 2024; Gould & Gomez, 2010; Rafi et al., 2019; Tait et al., 2016). There is also limited documentation of how these technologies may create both constraints and opportunities not only for library services, but also for wider developmental outcomes related to skills formation, knowledge access, and innovation readiness. This gap in the literature makes it difficult for policymakers, library managers, and educational stakeholders to formulate coherent strategies for technology-driven institutional transformation. As a result, Nigerian libraries risk remaining underprepared in a digital-first environment and may be less able to

contribute to the development of an innovation-oriented and knowledge-based economy.

The novelty of this study lies in repositioning the discussion of 4IR adoption in libraries from a predominantly institutional and service-oriented perspective to a broader developmental perspective that emphasizes human capital development and digital innovation. Rather than examining technology adoption solely in terms of library modernization, this study highlights its wider relevance to knowledge-based development, digital capability formation, and institutional readiness in an emerging economy context. This broader framing strengthens the relevance of the topic to economic development studies, particularly within debates on the knowledge economy, digital transformation, and innovation capacity in developing countries.

Against this background, this study conducts a systematic review of the literature on the adoption of Fourth Industrial Revolution technologies in Nigerian libraries, with particular attention to their implications for human capital development and digital innovation. Specifically, the study examines the current state of 4IR adoption, identifies the major challenges hindering implementation, explores the opportunities these technologies present for institutional transformation, and assesses the role of policy, infrastructure, and staff capacity in enabling or constraining adoption. By repositioning the discussion of 4IR technologies in libraries within a broader economic and developmental framework, this study seeks to provide evidence-based insights that can inform strategic planning, institutional reform, and policy support for more effective digital transformation in Nigerian libraries. In doing so, it contributes not only to the literature on library modernization, but also to the broader discourse on human capital formation and digital innovation in developing economies. The remainder of this article reviews the relevant literature, explains the systematic review methodology, presents the main findings, and discusses their implications for human capital development and digital innovation in the Nigerian context.

This study adopts a systematic review approach to synthesize existing literature on the adoption, challenges, and transformative potential of Fourth Industrial Revolution (4IR) technologies in Nigerian libraries (Pollock & Berge, 2018). The method was selected to provide a transparent, replicable, and comprehensive synthesis of empirical and theoretical studies on the subject. A qualitative systematic review design was employed, guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, to ensure a structured process of identification, screening, and analysis of relevant scholarly works (Selçuk, 2019). The literature search was conducted across several academic databases, including Scopus, Web of Science, Google Scholar, EBSCOhost, African Journals Online (AJOL), and Library and Information Science Abstracts (LISA). Search terms used in various combinations included “Fourth Industrial Revolution,” “4IR,” “Nigerian libraries,” “ICT in libraries,” “AI in libraries,” “IoT in libraries,” “digital transformation,” and “technology adoption in African libraries,” refined using Boolean operators (AND, OR). The search was limited to publications published between 2010 and 2024 to ensure currency.

The inclusion criteria covered peer-reviewed journal articles, theses, and conference papers focused on Nigerian or African libraries, discussing 4IR technologies or advanced ICT integration, and written in English. Excluded from the review were articles unrelated to libraries or technology adoption, opinion pieces, editorials, non-peer-reviewed sources, and studies published before 2010. A total of 168 articles were initially identified, and after screening for relevance, duplication,

and eligibility, 32 studies were selected for full review. From these studies, key information was extracted, including the type of 4IR technology discussed, library type, geographical focus, identified challenges or success factors, and reported outcomes or impacts. The extracted data were thematically analyzed to identify major patterns, trends, challenges, and opportunities, while the methodological quality of each study was assessed using a modified version of the Critical Appraisal Skills Programme (CASP) checklist, focusing on methodological clarity, relevance to the study objectives, and transparency of findings. Based on this review process, the findings of the study are organized into four major themes.

INTRODUCTION

Fourth Industrial Revolution Technologies and Library Transformation

The Fourth Industrial Revolution (4IR), characterized by the convergence of technologies such as artificial intelligence (AI), robotics, the Internet of Things (IoT), and big data, has transformed operations across industries, including the field of library and information science (Hossain, 2023). Globally, libraries are increasingly adopting these technologies to improve user engagement, streamline operations, and expand access to information (Meesad & Mingkhwan, 2024; Opele, 2023). In technologically advanced library systems, AI-driven cataloguing, robotic book retrieval, smart shelves, blockchain-based digital security, and immersive learning tools are becoming increasingly common (Oyedokun, 2025). These developments indicate that libraries are no longer merely repositories of information, but are evolving into more dynamic and technology-enabled knowledge institutions.

This transformation is important not only in terms of service modernization, but also in terms of institutional relevance in a digital era. Through 4IR technologies, libraries may become more efficient, user-centered, and data-driven, thereby improving their role in education, research support, and information management. In this regard, technology adoption in libraries can be interpreted as part of a broader process of digital innovation that enhances the institutional capacity of knowledge organizations.

Adoption Trends in Nigerian Libraries

In contrast to the progress recorded in technologically advanced contexts, the adoption of 4IR technologies in Nigerian libraries remains limited and uneven. While some university libraries have begun experimenting with digital repositories, automation systems, and selected smart technologies, the broader implementation of 4IR remains minimal observe that although some Nigerian university libraries have implemented automation software such as KOHA, more advanced technologies such as AI, IoT, and robotics are still largely aspirational (Oyedokun, 2025). Similarly, Odunlade & Ojo (2023) argue that most Nigerian libraries remain in a transitional phase, caught between traditional service models and the growing demands of digital transformation.

These findings suggest that Nigerian libraries have not yet fully entered the more advanced stage of technological modernization associated with 4IR. The current level of adoption appears to be concentrated in basic ICT integration and isolated innovation efforts rather than in deep, system-wide technological transformation. As a result, a significant gap remains between Nigerian libraries and their counterparts in more technologically advanced regions.

Structural Barriers to Technological Adoption

The literature identifies multiple barriers that constrain the adoption of 4IR technologies in Nigerian libraries. These include poor funding, inadequate infrastructure, unreliable electricity supply, weak internet connectivity, lack of technical expertise, and resistance to organizational change (Idemudia et al., 2023; Singh et al., 2015). These factors create a structural environment in which technology adoption is difficult to implement and sustain. Even where institutions express awareness of the importance of digital transformation, the absence of foundational infrastructure often prevents advanced technologies from being effectively deployed.

Institutional and policy limitations further complicate the situation. Agboola (2025) notes that many Nigerian libraries lack clear digital transformation strategies, while Khan et al (2023) emphasizes that national policy frameworks for library technology modernization remain weak or insufficiently enforced. These gaps reduce the possibility of structured implementation, scaling, and long-term sustainability. In many cases, technological initiatives remain fragmented, pilot-based, or donor-dependent, rather than integrated into broader institutional strategies.

Another major barrier highlighted in the literature is the issue of human capacity. Habibu et al (2012) report that even in institutions with some ICT infrastructure, the lack of adequate staff training significantly limits effective utilization. Moonasar (2024) similarly argues that continuous professional development and curriculum reform in library education are needed to prepare librarians for 4IR environments. This suggests that the challenge of 4IR adoption is not only technical or financial, but also deeply connected to workforce readiness and institutional learning capacity.

Human Capital Development and Digital Innovation

The relevance of 4IR adoption in libraries extends beyond institutional modernization and into the broader domains of human capital development and digital innovation. Libraries play an important role in supporting learning, research, digital literacy, and knowledge access. As such, they contribute to the development of human capital by strengthening digital competencies, facilitating educational advancement, and improving access to knowledge resources. The integration of 4IR technologies may enhance this function by creating more innovative learning environments, improving research support systems, and enabling broader participation in digital knowledge ecosystems.

From the perspective of digital innovation, 4IR technologies may also improve the efficiency and responsiveness of library services. Automation systems, intelligent search tools, RFID, analytics platforms, and digital content management can support better service delivery, more efficient resource management, and stronger inter-institutional knowledge sharing (Mohammed & Amoah, 2025). These developments may position libraries as active contributors to the digital economy, particularly in contexts where knowledge institutions are expected to support innovation capacity and digital readiness.

The literature also points to emerging use cases that demonstrate the feasibility of such transformation in Nigeria. For example, Fagbola et al (2023) report that the University of Ibadan Library has experimented with RFID-based inventory management and AI-powered indexing tools. Although still limited in scale, such initiatives suggest that Nigerian libraries can adopt 4IR technologies when

appropriate support structures are in place. In this sense, the modernization of libraries may contribute not only to better institutional performance, but also to broader developmental goals related to digital innovation and the strengthening of human capital in a knowledge-based economy.

Research Gap and Analytical Positioning

The reviewed literature shows that awareness of 4IR technologies in libraries has grown, but implementation in Nigeria remains uneven and constrained by structural, institutional, and human resource limitations. Existing scholarship has been useful in documenting adoption trends, barriers, and selected innovation cases. However, much of the literature still discusses 4IR adoption primarily from the perspective of library modernization and service delivery. Less attention has been given to its wider implications for human capital development and digital innovation, particularly within the context of economic development.

This study addresses that gap by repositioning the discussion of 4IR technologies in Nigerian libraries within a broader developmental framework. Rather than treating technological adoption solely as an institutional issue, the study highlights its relevance to human capital formation, digital capability development, and innovation-oriented transformation. In doing so, it strengthens the connection between library transformation and the economic significance of knowledge institutions in a digital era.

RESULTS AND DISCUSSION

Result

The review of 32 eligible studies indicates that awareness of Fourth Industrial Revolution (4IR) technologies has increased considerably among librarians, library administrators, and information professionals in Nigeria. Across the reviewed literature, technologies such as artificial intelligence (AI), the Internet of Things (IoT), blockchain, robotics, RFID, and smart systems are increasingly recognized as important tools for improving library operations, expanding access to information, and modernizing service delivery. This growing awareness suggests that the discourse on digital transformation is gaining visibility within the Nigerian library sector. In many institutions, library professionals appear to understand the strategic relevance of 4IR technologies for enhancing efficiency, user engagement, and institutional relevance in a digital environment. However, the findings also reveal that awareness has not yet translated into widespread or deep implementation. In this sense, there is a clear gap between technological recognition and actual institutional adoption.

The studies reviewed show that the level of adoption remains low and uneven across different library types. Academic libraries demonstrate the highest level of ICT integration and technological experimentation, although this is still largely limited to relatively basic or transitional forms of digitalization, such as automation systems, RFID applications, and digital repositories. These tools represent important early steps toward modernization, but they do not yet reflect comprehensive 4IR transformation at the level seen in more technologically advanced library systems. Public and school libraries, by contrast, report minimal or no implementation of 4IR technologies, indicating a much lower level of readiness and institutional capacity. This disparity suggests that adoption is shaped not only by technological awareness, but also by differences in funding, infrastructure, administrative support, and organizational priorities across library categories. The

absence of documented use of robotics and blockchain in the reviewed studies further reinforces the conclusion that 4IR adoption in Nigerian libraries remains at an emerging rather than mature stage. Overall, the evidence suggests that Nigerian libraries are still positioned within an early phase of digital transition, in which awareness is growing faster than practical implementation. From a broader developmental perspective, this limited level of adoption implies that the potential contribution of libraries to human capital development and digital innovation remains underutilized, particularly because technology-enabled learning environments, advanced information systems, and innovation-support services have not yet been widely institutionalized.

Benefits and Transformation Opportunitiess

Despite the still limited level of adoption, the reviewed studies highlight several important transformation opportunities associated with the integration of Fourth Industrial Revolution (4IR) technologies in Nigerian libraries. The literature suggests that technologies such as automation tools, RFID, IoT-based systems, cloud platforms, and analytics applications have the potential to significantly improve service delivery and operational efficiency. For example, automation and self-checkout systems can reduce routine manual workloads, shorten transaction times, and improve the overall user experience. Similarly, smart inventory systems and IoT-based tracking tools can strengthen resource management by enabling more accurate monitoring of collections, reducing loss, and improving circulation processes. These developments indicate that 4IR technologies may enhance the functional efficiency of libraries and support a transition toward more responsive and technology-driven service models.

The findings also suggest that 4IR adoption may expand the role of libraries in improving access to knowledge resources and supporting digital inclusion. Cloud-based platforms and mobile applications, for instance, offer opportunities for remote access to library materials, making knowledge resources more accessible beyond the physical library space. This is especially relevant in contexts where geographical distance, institutional limitations, or uneven infrastructure constrain access to information. In addition, data analytics tools may enable evidence-based decision-making by helping library managers understand user needs, monitor service patterns, and allocate resources more effectively. Such capabilities may strengthen the strategic role of libraries in providing information services that are more adaptive, data-informed, and aligned with the changing demands of digital users. From this perspective, the transformation potential of 4IR technologies extends beyond operational modernization and touches on broader issues of knowledge access, learning support, and digital readiness.

One notable example identified in the literature is the implementation of RFID technology at the University of Ilorin Library, which improved book tracking and circulation efficiency (Fagbola et al., 2023). Although such examples remain limited, they demonstrate that the adoption of advanced technologies in Nigerian libraries is feasible when supported by adequate institutional commitment and technical capacity. More broadly, these opportunities suggest that 4IR technologies may contribute to human capital development by improving access to learning resources, supporting digital competencies, and creating more innovative information environments. At the same time, they may foster digital innovation through better service efficiency, improved information management, and stronger institutional capacity to operate in a technology-enabled knowledge economy. Therefore, even though current implementation remains partial, the literature

indicates that the transformative potential of 4IR technologies in Nigerian libraries is significant if supported by sustained investment, strategic planning, and capacity development.

Major Barriers to Adoption

The reviewed literature consistently identifies several major barriers that hinder the adoption of Fourth Industrial Revolution (4IR) technologies in Nigerian libraries. One of the most frequently cited challenges is inadequate funding for advanced technological infrastructure, which significantly constrains the ability of libraries to acquire, install, maintain, and upgrade digital systems (Okiki, 2019). In many institutions, financial limitations make it difficult to move beyond basic ICT integration toward more sophisticated technologies such as AI, IoT, smart systems, and advanced analytics. This problem is further compounded by weak ICT infrastructure, including unreliable electricity supply, low internet bandwidth, and insufficient access to stable digital platforms. Under such conditions, even when institutions recognize the relevance of 4IR technologies, implementation often remains impractical or unsustainable.

Another major obstacle concerns the issue of human capacity. The literature points to poor digital literacy and limited technical training among library staff as important constraints on effective adoption (Udo-Anyanwu & Nwachukwu, 2022). The successful integration of 4IR technologies requires not only physical infrastructure but also a workforce capable of operating, managing, and adapting to new digital systems. However, many library professionals in Nigeria have not received adequate training to engage confidently with more advanced technologies. As a result, the challenge of adoption is not only technological but also organizational and educational. Limited staff capacity reduces the ability of libraries to fully utilize available infrastructure, weakens institutional readiness for innovation, and slows the transition toward more digitally responsive service models.

Institutional and policy-related barriers also remain significant. The lack of a national policy or strategic framework guiding 4IR implementation in libraries has been identified as a key factor limiting coordinated and large-scale adoption ((Onuoha, 2021). Without clear policy direction, many institutions pursue digital initiatives in fragmented and unstructured ways, often without long-term planning or sustainable support mechanisms. In addition, resistance to change among senior staff and library leadership in some institutions further constrains technological transformation. This resistance may stem from uncertainty, lack of technical confidence, or concerns about organizational disruption. Taken together, these barriers suggest that the adoption of 4IR technologies in Nigerian libraries is shaped by a complex interaction of financial, infrastructural, human, and institutional constraints. From a broader developmental perspective, these obstacles also limit the capacity of libraries to contribute more effectively to human capital development and digital innovation.

Institutional Readiness and Strategic Gaps

The reviewed studies suggest that institutional readiness for the adoption of Fourth Industrial Revolution (4IR) technologies in Nigerian libraries remains generally weak. Only a limited number of institutions were found to have clear digital transformation strategies, dedicated implementation plans, or allocated budgets for technological upgrading. In many cases, awareness of the importance of digital transformation exists at the institutional level, yet this awareness is not consistently translated into concrete planning, structured investment, or long-term strategic

commitment. As a result, technological adoption often occurs in a fragmented and reactive manner rather than as part of a coherent institutional modernization agenda.

Where attempts at technological innovation have been made, they are frequently donor-driven, externally initiated, or implemented as short-term pilot projects rather than as sustainable institutional programs. This pattern indicates that many libraries still depend on temporary support rather than internally grounded strategic readiness. A notable example is the IoT pilot project for smart shelf management at a private university, which was eventually discontinued because of inadequate technical support and insufficient maintenance funding (Ozioko & Nwafor, 2021). This case demonstrates that the introduction of new technology alone is not enough; sustained adoption requires organizational commitment, technical continuity, and financial planning beyond the pilot stage.

These strategic gaps highlight a broader institutional challenge in the Nigerian library sector. Without clear transformation roadmaps, stable budgetary support, and mechanisms for technical maintenance and staff development, the potential benefits of 4IR technologies are unlikely to be fully realized. Weak institutional readiness also limits the capacity of libraries to function as innovation-supporting knowledge institutions within a digital economy. From the perspective of human capital development, this means that libraries may be less able to provide the digital environments, knowledge services, and learning support necessary for strengthening digital competencies and innovation capacity. Therefore, improving institutional readiness is essential not only for successful technology adoption, but also for enabling libraries to contribute more effectively to broader developmental and economic goals.

Discussion

The findings of this systematic review reveal that the adoption of Fourth Industrial Revolution (4IR) technologies in Nigerian libraries is characterized by a mixture of growing awareness, limited implementation, and significant untapped developmental potential. On the one hand, the reviewed literature shows that library professionals and administrators in Nigeria are increasingly aware of the importance of technologies such as artificial intelligence (AI), the Internet of Things (IoT), RFID, robotics, and smart systems in reshaping information services and library operations. On the other hand, actual adoption remains relatively low and uneven across institutions. This gap between awareness and implementation is one of the central patterns emerging from the review and reflects a broader condition of digital transition rather than full technological transformation. In this sense, Nigerian libraries appear to be situated in an early stage of 4IR integration, where the discourse of innovation is advancing faster than institutional readiness and operational change. This finding is consistent with earlier studies showing that while libraries globally are moving toward smart and technology-enabled models, the pace of transition in Nigeria remains constrained and incomplete (Chigona et al., 2024; Das et al., 2026; Ozioko & Nwafor, 2021).

A major explanation for this pattern lies in the interaction between structural limitations and institutional capacity. The literature reviewed consistently points to inadequate funding, weak ICT infrastructure, unreliable electricity supply, poor broadband access, and limited technical expertise as critical barriers to adoption (Alabdali et al., 2023; Touray et al., 2013). These constraints are particularly important because 4IR technologies are not stand-alone tools that can simply be introduced into any organizational environment. Their adoption requires a stable

digital ecosystem, including reliable power, internet connectivity, technical maintenance systems, and staff capable of managing more advanced digital infrastructures. In settings where these foundational conditions are weak, adoption is likely to remain shallow, fragmented, or unsustainable. Thus, the barriers identified in Nigerian libraries should not be understood merely as operational inconveniences; rather, they represent structural conditions that directly shape the capacity of knowledge institutions to participate in digital transformation. This also explains why even libraries with some level of ICT integration have not necessarily progressed toward deeper 4IR implementation.

The review also demonstrates that technological adoption differs considerably across library types. Academic libraries emerge as the most active sites of experimentation and partial integration, mainly through automation systems, RFID-based circulation management, and digital repositories. By contrast, public and school libraries appear to remain far behind, with minimal or no documented use of advanced 4IR technologies. This uneven pattern suggests that adoption is strongly shaped by institutional differentiation. Academic libraries are generally more likely to be connected to universities, research agendas, external grants, and professional networks that expose them to digital innovation. Public and school libraries, however, may face stronger fiscal constraints, weaker policy attention, and lower institutional autonomy. This disparity matters because it implies that the developmental benefits of 4IR adoption are also likely to be distributed unevenly across the library sector. If advanced technologies remain concentrated in a few relatively privileged institutions, then the broader role of libraries in supporting inclusive access to knowledge, digital skills, and innovation capacity will remain limited. Therefore, the issue is not simply whether 4IR technologies are being introduced, but also where, for whom, and under what institutional conditions they are being adopted.

One of the key contributions of this study is to interpret these findings beyond the narrow frame of library modernization and to connect them to broader questions of human capital development. Libraries are not only service points for books and information; they are also institutions that support learning, research, knowledge circulation, and digital literacy. In this regard, the adoption of 4IR technologies may have implications that extend far beyond internal operational efficiency. When libraries adopt intelligent search systems, digital repositories, RFID-enabled circulation, cloud-based access, and analytics-supported services, they improve the conditions under which users learn, conduct research, access information, and build digital competencies. Such improvements can strengthen human capital by enhancing the availability, accessibility, and usability of knowledge resources. This perspective is particularly important in a country like Nigeria, where educational systems and knowledge institutions face persistent pressures related to quality, access, and digital inequality. From this standpoint, the technological transformation of libraries should be understood as part of a wider process of capability formation in the knowledge economy.

The findings on digital skills and staff readiness reinforce this interpretation. The literature highlights poor digital literacy and insufficient technical training among library staff as recurring obstacles to effective technological adoption (Rahman et al., 2024; Udo-Anyanwu & Nwachukwu, 2022). This issue is highly significant because staff capacity is central to both technological functionality and developmental impact. Even where infrastructure exists, technology cannot generate meaningful transformation if staff members lack the competence to manage, adapt, and use it strategically. More importantly, librarians themselves are

part of the human capital base of the educational and information system. Their ability to operate in a 4IR environment shapes not only internal service quality but also the digital experience of users. If librarians are insufficiently trained, libraries may be unable to support users in navigating digital resources, data-driven services, and new modes of knowledge access. Accordingly, workforce development emerges as a central mechanism linking 4IR adoption to broader developmental outcomes. In other words, investment in technology without investment in people is unlikely to produce sustainable innovation.

The review findings also point to the relevance of 4IR technologies for digital innovation. In the literature, digital innovation is reflected not only in the adoption of new tools but in the reconfiguration of institutional practices, service delivery systems, and user engagement mechanisms. Nigerian libraries that have adopted automation, RFID, digital repositories, and selected smart systems are already showing early signs of this transformation. For example, the implementation of RFID technology at the University of Ilorin Library improved book tracking and circulation efficiency, demonstrating how even relatively targeted interventions can generate meaningful gains in library management and service quality (Fagbola et al., 2023). Similarly, the literature notes that automation systems, cloud-based platforms, mobile access, and analytics tools can improve service efficiency, support remote access, and facilitate more informed decision-making (Mithun & Sultana, 2024a). These developments suggest that libraries have the potential to function not only as users of innovation, but also as institutional environments in which digital innovation becomes operationalized and sustained.

At the same time, the discussion must remain cautious in assessing the depth of this innovative transformation. The absence of documented adoption of robotics and blockchain in the reviewed studies, as well as the discontinuation of certain pilot initiatives, indicates that most Nigerian libraries have not yet achieved mature 4IR integration. A telling example is the IoT-based smart shelf pilot in a private university, which was discontinued due to inadequate technical support and maintenance funding (Mithun & Sultana, 2024b). This case illustrates a broader challenge of institutional sustainability. Innovation in developing contexts often begins with pilot projects, donor support, or isolated experiments, but these initiatives do not necessarily lead to long-term transformation unless they are embedded in broader organizational strategies. Therefore, one of the most important findings of this review is that institutional readiness remains weak. Only a few institutions were reported to have clear digital transformation strategies, dedicated budgets, or long-term implementation plans. This suggests that the problem is not only one of technological availability, but also one of strategic governance. Without a coherent institutional vision, libraries are unlikely to convert isolated innovation efforts into sustainable developmental gains.

From a policy perspective, these findings have important implications. First, the reviewed evidence indicates that the digital transformation of libraries should be approached as a development issue rather than merely as a technical upgrade. Because libraries contribute to education, research, information access, and digital capability formation, their modernization has implications for human capital development and innovation readiness. Second, stronger policy frameworks are needed at both national and institutional levels. The literature points to the lack of strategic direction and policy support as a major barrier to implementation (Fischer et al., 2016; Vigfússon et al., 2021). In practical terms, this means that library transformation should be embedded within broader national agendas related to digital infrastructure, education policy, public sector modernization, and

knowledge economy development. Third, capacity-building must be treated as a core pillar of transformation. Training librarians and technical staff is not an auxiliary concern but a central investment in the human capital necessary to sustain technological change. Finally, more sustainable financing mechanisms are essential. Given the recurring problem of underfunding, the review supports the idea that partnerships, institutional investment models, and externally supported innovation programs may play a role in expanding technological readiness, provided that they are linked to long-term strategic objectives rather than short-lived experimentation.

The broader significance of these findings lies in the repositioning of Nigerian libraries within the economic discourse of digital transformation. Much of the existing literature approaches the issue from the standpoint of library service delivery, modernization, and access to information. While these remain important, the present review suggests that the discussion should be widened to include the developmental and economic significance of libraries as knowledge institutions. In an increasingly digital economy, institutions that facilitate access to knowledge, support lifelong learning, enhance digital skills, and strengthen research capability are part of the broader infrastructure of human capital and innovation. The limited adoption of 4IR technologies in Nigerian libraries therefore represents not only an institutional gap, but also a missed developmental opportunity. Conversely, greater technological integration in libraries could support a more knowledge-intensive and innovation-oriented development trajectory by enhancing educational resources, research support, and digital competence formation. This is what makes the issue relevant not only for library studies, but also for economic development analysis.

Overall, the discussion confirms that the landscape of 4IR adoption in Nigerian libraries is both constrained and promising. The reviewed literature makes clear that awareness is growing and that some institutions have begun to experiment with meaningful forms of digital transformation. Yet implementation remains uneven, fragile, and structurally constrained. The most significant barriers are not only technological but also institutional, financial, and human-capacity related. At the same time, the opportunities are substantial: more efficient service delivery, improved information management, expanded digital access, stronger learning environments, and enhanced institutional support for human capital development and digital innovation. These findings suggest that the future contribution of Nigerian libraries to the knowledge economy will depend on whether 4IR adoption can move from fragmented experimentation to sustained, strategically supported transformation. In this regard, the challenge is not simply to introduce new technologies, but to create the institutional, policy, and human foundations that allow those technologies to generate meaningful and lasting developmental impact.

CONCLUSION

Adoption of Fourth Industrial Revolution (4IR) technologies in Nigerian libraries remains at an emerging and uneven stage, characterized by growing awareness but limited implementation due to persistent financial, infrastructural, institutional, and human capacity constraints. Although current adoption is still largely concentrated in basic automation, RFID, and digital repository systems, the findings indicate that these technologies hold significant potential to improve service efficiency, strengthen information management, expand access to knowledge resources, and support more innovative learning and research environments. From

a broader developmental perspective, the integration of 4IR technologies in libraries may contribute to human capital development by enhancing digital competencies and knowledge access, while also supporting digital innovation within the knowledge economy. However, realizing this potential requires stronger strategic frameworks, sustained investment in infrastructure, continuous staff capacity building, and institutional commitment to long-term digital transformation.

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The author declares no conflict of interest.

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BIBLIOGRAPHY
Adekoya, C. O., Fasae, J. K., & Alade, A. V. (2024). Academic libraries, ICT use and sustainable higher education development. *Information Discovery and Delivery*, *52*(1), 1–10.

Agboola, B. (2025). Financial Inclusion in the Last Decade: A Systematic Literature Review. *International Journal of Research and Innovation in Social Science (IJRISS)*, *9*(10).

Alabdali, S. A., Pileggi, S. F., & Cetindamar, D. (2023). Influential factors, enablers, and barriers to adopting smart technology in rural regions: A literature review. *Sustainability*, *15*(10), 7908.

Chigona, W., Kabanda, S., & Seymour, L. F. (2024). Implications of Information and Digital Technologies for Development. *18th IFIP WG 9.4 International Conference, ICT4D 2024*.

Das, D. K., Aiyetan, A. O., & Mostafa, M. M. H. (2026). Advancing Smart Cities in Africa: Barriers, Potentials, and Strategic Pathways for Sustainable Urban Transformation. *Smart Cities*, *9*(2), 38.

Fagbola, T. M., Ajegbomogun, F. O., & Ogunmodede, T. A. (2023). Adoption of RFID technology in academic libraries in Nigeria: Prospects and challenges. *Library Hi Tech News*, *40*(2), 14–20.

Fischer, F., Lange, K., Klose, K., Greiner, W., & Kraemer, A. (2016). Barriers and strategies in guideline implementation—a scoping review. *Healthcare*, *4*(3), 36.

Gould, E., & Gomez, R. (2010). New challenges for libraries in the information age: A comparative study of ICT in public libraries in 25 countries. *Information Development*, *26*(2), 166–176.

Habibu, T., Abdullah-Al-Mamun, M. D., & Clement, C. (2012). Difficulties faced by teachers in using ICT in teaching-learning at technical and higher educational institutions of Uganda. *International Journal of Engineering Research & Technology (IJERT)*, *1*(7), 1–9.

Haruna, A. (2025). Revitalizing Nigerian Libraries through Digital Infrastructure: A Blueprint for Equitable National Knowledge Access. *Journal of Science Innovation and Technology Research*.

Hossain, K. A. (2023). Analysis of present and future use ofartificial intelligence (ai) in line of fouth industrial revolution (4ir). *Scientific Research Journal*, *11*(8), 1–50.

Idemudia, S. O., Chima, O. K., Ezeilo, O. J., Ojonugwa, B. M., & Adesuyi, A. (2023). Digital infrastructure barriers faced by SMEs in transitioning to smart business models. *International Journal of Scientific Research in Science, Engineering and Technology*, *10*(4), 353–370.

Khan, A. U., Rafi, M., Zhang, Z., & Khan, A. (2023). Determining the impact of technological modernization and management capabilities on user satisfaction and trust in library services. *Global Knowledge, Memory and Communication*, *72*(6–7), 593–611.

Logeswaran, K., Savitha, S., Suresh, P., Prasanna Kumar, K. R., Gunasekar, M., Rajadevi, R., Dharani, M. K., & Jayasurya, A. S. (2024). Unifying technologies in industry 4.0: Harnessing the synergy of internet of things, big data, augmented reality/virtual reality, and blockchain technologies. *Topics in Artificial Intelligence Applied to Industry 4.0*, 127–147.

Meesad, P., & Mingkhwan, A. (2024). Emerging technologies in smart digital libraries. *Libraries in Transformation: Navigating to AI-Powered Libraries*, 211–270.

Mithun, S., & Sultana, R. (2024a). The Influence of Cloud-Based Management Information Systems on Remote Work Efficiency. *Strategic Data Management and Innovation*, *1*(01), 1–7.

Mithun, S., & Sultana, R. (2024b). The Influence of Cloud-Based Management Information Systems on Remote Work Efficiency. *Strategic Data Management and Innovation*, *1*(01), 1–7.

Mohammed, A. S., & Amoah, C. (2025). Integration of technology in decision-making in university facilities management: a literature review. *Facilities*, *43*(13–14), 1018–1052.

Moonasar, A. (2024). Continuing professional development and the changing landscape of academic libraries. *Library Management*, *45*(3–4), 226–242.

Odunlade, R., & Ojo, J. (2023). Digital transformation and service delivery in academic libraries: A post Covid-19 approach. *Lokoja Journal of Information Science Research*, *1*(1), 41–60.

Okiki, O. C. (2019). Challenges of information and communication technology (ICT) adoption in Nigerian libraries. *African Journal of Library, Archives and Information Science*, *29*(1), 45–54.

Onuoha, U. D. (2021). The role of policy in library automation and digital transformation in Nigeria. *Nigerian Libraries*, *54*(2), 32–44.

Opele, J. K. (2023). The impact of emerging technologies on library education: A global perspectives. *University of Ibadan Journal of Library and Information Science*, *6*(2).

Oyedokun, T. T. (2025). Reimagining libraries in the fifth industrial revolution (5IR): The impact of robotics, artificial intelligence (AI), metaverse, blockchain, and emerging technologies. *Business Information Review*, *42*(2), 112–124.

Ozioko, R. E., & Nwafor, B. U. (2021). Internet of Things (IoT) and smart library systems: Case study of a pilot implementation in a Nigerian private university. *Journal of Information Science Theory and Practice*, *9*(4), 25–38.

Pollock, A., & Berge, E. (2018). How to do a systematic review. *International Journal of Stroke*, *13*(2), 138–156.

Rafi, M., JianMing, Z., & Ahmad, K. (2019). Technology integration for students' information and digital literacy education in academic libraries. *Information Discovery and Delivery*, *47*(4), 203–217.

Rahman, M. H., Ahmad, A. Bin, & Mohamed Sawal, M. Z. H. Bin. (2024). The influence of personal factors on resistance to technology adoption in university libraries in Bangladesh. *Information Development*, 02666669241257196.

Sandhu, G. (2018). The role of academic libraries in the digital transformation of the universities. *2018 5th International Symposium on Emerging Trends and Technologies in Libraries and Information Services (ETTLIS)*, 292–296.

Selçuk, A. A. (2019). A guide for systematic reviews: PRISMA. *Turkish Archives of Otorhinolaryngology*, *57*(1), 57.

Singh, R., Wang, X., Mendoza, J. C., & Ackom, E. K. (2015). Electricity (in) accessibility to the urban poor in developing countries. *Wiley Interdisciplinary Reviews: Energy and Environment*, *4*(4), 339–353.

Tait, E., Martzoukou, K., & Reid, P. (2016). Libraries for the future: the role of IT utilities in the transformation of academic libraries. *Palgrave Communications*, *2*(1), 16070.

Touray, A., Salminen, A., & Mursu, A. (2013). ICT barriers and critical success factors in developing countries. *The Electronic Journal of Information Systems in Developing Countries*, *56*(1), 1–17.

Udo-Anyanwu, A. J., & Nwachukwu, V. N. (2022). Digital literacy and 4IR technology readiness among librarians in Nigerian universities. *Library Philosophy and Practice (e-Journal)*, 6741.

Vigfússon, K., Jóhannsdóttir, L., & Ólafsson, S. (2021). Obstacles to strategy implementation and success factors: A review of empirical literature. *Strategic Management-International Journal of Strategic Management and Decision Support Systems in Strategic Management*, *26*(2).